ario hydro

Research and Development

The Commission

Head Office: 620 University Avenue, Toronto, Ontario M5G 1X6
Research Division: 800 Kipling Avenue, Toronto, Ontario M8Z 5S4

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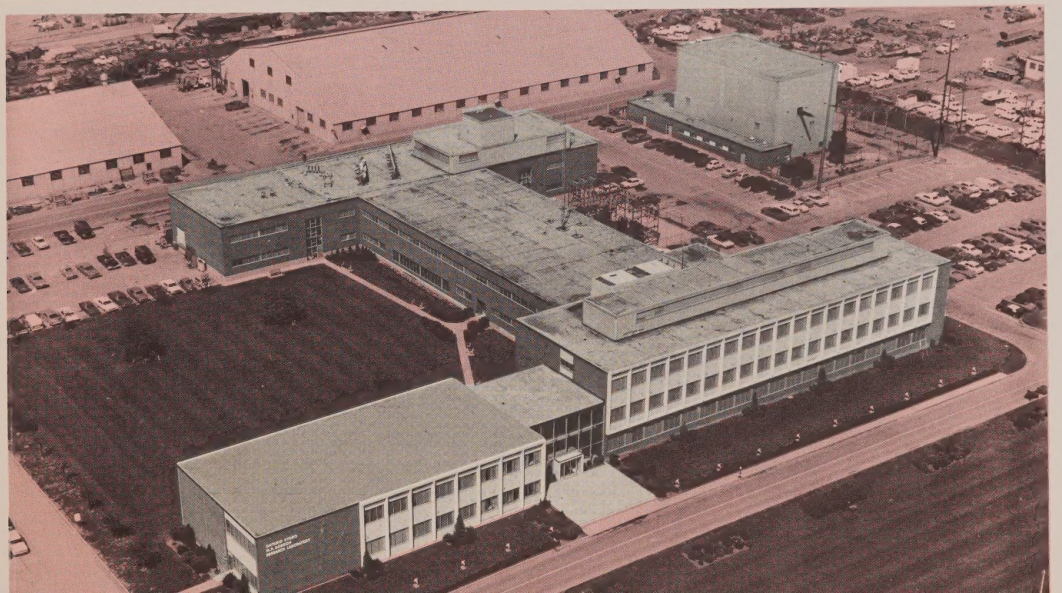


THE RESEARCH DIVISION

ONTARIO HYDRO not only operates its power system but also largely designs and builds the necessary structures. The present rate of load growth in Ontario, calling for a doubling of generating capacity within the next ten years, with a similar rate predicted for later decades, presents a formidable engineering challenge. Numerous technological problems of increasing complexity are arising as the power system becomes larger, relating not only to the design and construction of the system but also to its operation and maintenance. Other important problems stem from the ever-widening applications of electrical energy in industry and commerce and in the residential sphere, and as such relate to the efficient, safe and economical use of electricity.

In plans to meet the challenge of these problems the Research Division has an important and essential role. Its broad objective is to help, through continuous investigation and development, to solve the problems of today, to anticipate and avoid those of tomorrow, and to ensure that the most advanced and preferred engineering practices, consistent with sound economy, are applied. In addition to the longer-term research effort on major projects, much investigation and testing work is done, frequently at the request of other organization units of Ontario Hydro, to aid the solution of day-by-day technical problems. Similar work finds application in the development of Ontario Hydro material and performance specifications and standards, and in the quality control of materials and items purchased.

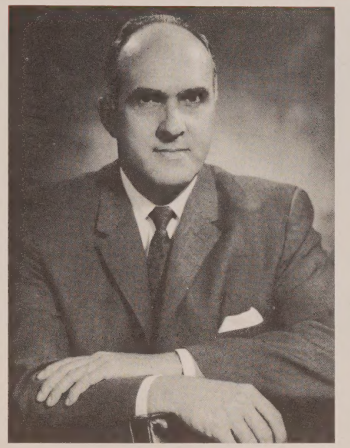
Through contacts maintained with the research units of other major electric-power utilities and with research agencies having related interests, technical information is exchanged on topics of a wide range. Also, staff members participate in the committee work of technical societies and of standardizing bodies, and contribute papers to the technical literature. In addition to benefiting Ontario Hydro, these activities help to advance technology in the electric-power field and in related fields of engineering and science.

Much of the Research Division's work is performed in the modern laboratory pictured on the front cover. Named in honour of Dr. W. P. Dobson, Director of Research from 1914 to 1953, this electrically heated and air-conditioned building was first occupied in 1961. Along with the adjacent high-voltage laboratory, it provides some 150,000 square feet of accommodation. Other work of the Division includes field services performed wherever required in the Province; these play a highly important part, of course, in the over-all functions.

The main areas of investigation of the Division are indicated on the last page,

following the illustrations and brief outlines of some of the work.

As in the past six decades, the Division's aim for the future will be to continue to provide technical services of the highest possible standard. Furthered by modern laboratory facilities and a well qualified staff of about 360, intensive research in many of the problem areas that now exist or are likely to develop or become more serious with time, will substantially assist Ontario Hydro and thus the co-operating municipal untilities to maintain a modern, abundant and high-standard supply of economical electric power throughout the Province.



H. A. Smith,
Chief Engineer,
Ontario Hydro

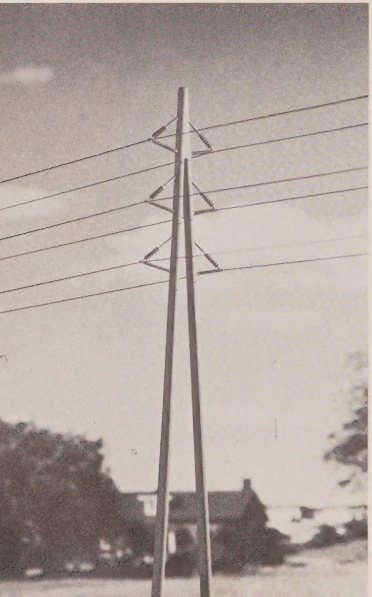
J. H. Waghorne,
Director of Research

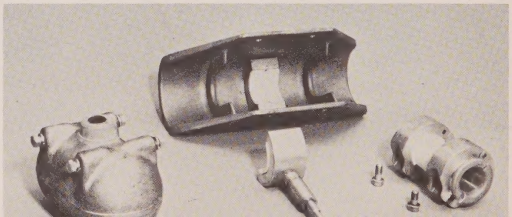
Transmission

Research on "compact lines" could lead to reductions of tower-head dimensions of as much as 50 per cent. Towers of the type shown below, using improved insulators and new methods of galloping control, would be 30 per cent shorter and require less right of way than conventional towers, and would lead toward transmission lines of reduced visibility and improved appearance.

Essential to the development of compact lines is a method of controlling the galloping of iced conductors in cross-winds. The torsional damper shown below would inhibit galloping by damping wind-induced torsional oscillations which lead to high-amplitude translational oscillations of line conductors. Developed in 1971, the devices have undergone extensive field tests and are now in trial service on several operating lines in southern Ontario.

As part of the compact line studies these line insulators are subjected in a fog chamber to severe conditions of dirt, moisture and electric stress. The effects of insulator shapes, materials, and surface treatments are investigated with the aim of obtaining better performance from shorter strings of insulators.

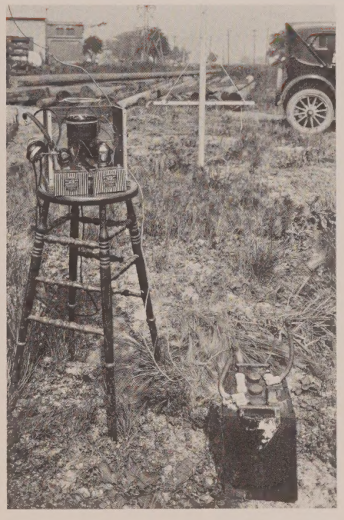


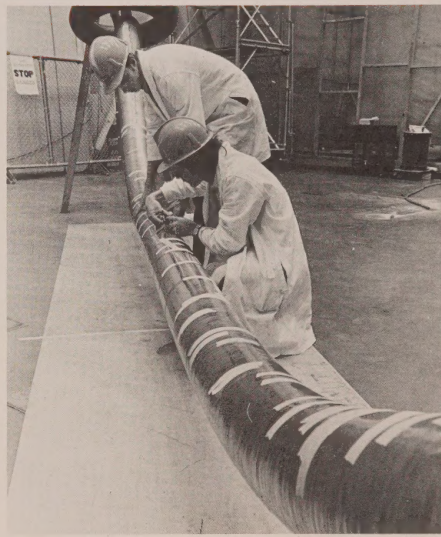


Electric discharge phenomena of ehv transmission-line conductors and insulators are investigated under controlled laboratory conditions. The corona test cage reproduces high-voltage corona effects at moderate voltages and is used in the development of methods of limiting radio interference from high-voltage lines and equipment.

In 1924 the Research Department conducted experiments in coupling carrier frequency signals onto high-voltage transmission lines. The equipment, based on the newly developed electron tube, was powered by electro-chemical energy storage units. An up-to-date transportation unit stood at the ready during these field experiments.

Because of problems attendant with overhead transmission-line takeouts from large generating stations, considerable importance attaches to the development of underground transmission facilities of higher reliability and lower capital cost than conventional underground cables now offer. One design being considered for distances of five to 20 miles uses three air-insulated tubular conductors in a buried duct. Below, a section of tubing is being prepared for tests that establish the basic air-gap characteristics of the conductor in a uniform field.

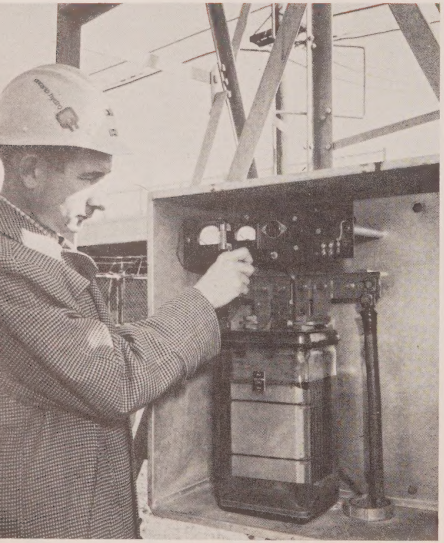


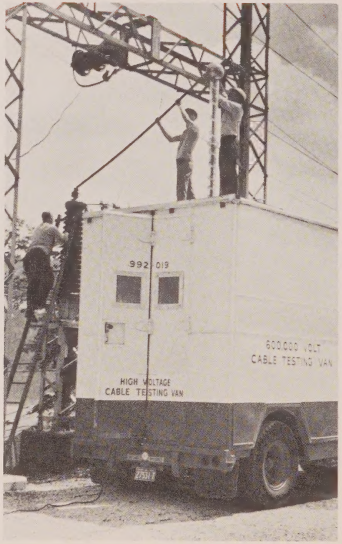


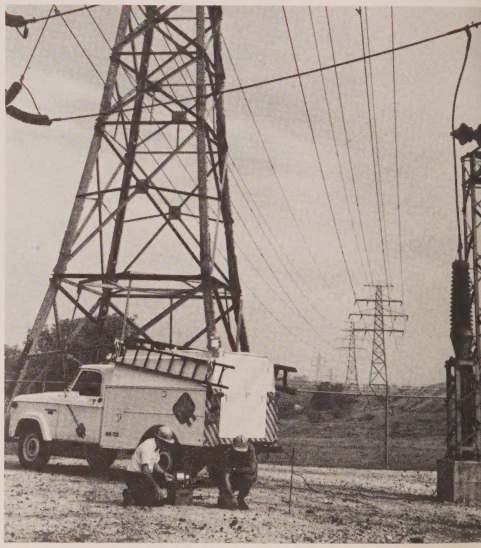
For underground cables, security of operation can be improved by providing adequate corrosion protection. Special test techniques for coating materials are developed and new protective coatings are evaluated on a continuing basis. This work also calls for testing of new materials both in the laboratory and in the field. In addition, cathodic protection is often applied to inhibit corrosion. Such a protection scheme is shown being adjusted.

Electrical-fault location and high-voltage testing of cables are performed in the field from this mobile test van provided with a 600,000-volt dc supply and pulse-echo-type fault-locating equipment. The van is used for acceptance tests on newly installed cables and on insulated-bucket trucks, and for location of faults in cables in service.

The trend to underground power transmission prompts the development of aids to effective cable maintenance. A highly selective instrument for locating leaks in gas-pressurized cables is shown. It comprises basically a gas-separating column and a halogen detector. A method for locating leaks in oil-pressurized cables is based on sensitive measurement of small oil flows. Several promising new methods which make use of oil-pressure or electrical transients, acoustical noise, and tracers in cable oil are under study.



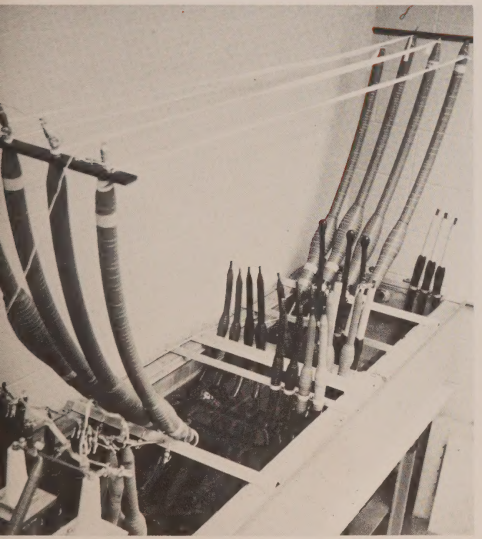


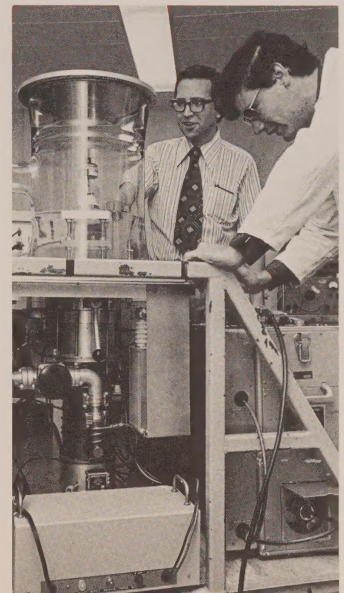


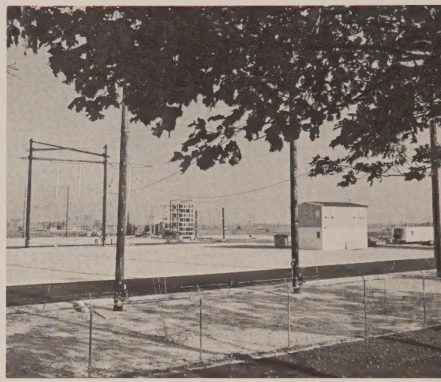
Most cable failures, other than from accidental dig-ins, occur at cable terminations and splices. Improved techniques for splicing and terminating distribution cable are developed, increasing service reliability. These developments also help to minimize the number of inventory items required for splicing or terminating all cable types. Cable splices, including those involving materials and procedures offered commercially, are evaluated in a temperature-cycling water bath.

The use of new extruded insulating materials in high-voltage cables has made it necessary to develop techniques for evaluation of such materials. Controlled microscopic breakdown of insulation samples is induced by electron bombardment for study of the mechanisms of insulation failure. A research program is also under way to establish effective ways of accelerating the aging process in large cable samples and accessories up to the 230-kV class. In addition to conventional approaches such as impulse and over-voltage testing, the application of high-voltages at frequencies up to 3000 Hz is actively studied.

An outdoor high-voltage laboratory near Kleinburg provides for 60 Hz and switching-surge testing of full-scale transmission structures up to the 500-kV design level. Used initially for development of compact overhead lines, the installation is being extended for trial installations of prototype air-insulated and pressurized-gas-insulated underground transmission systems.



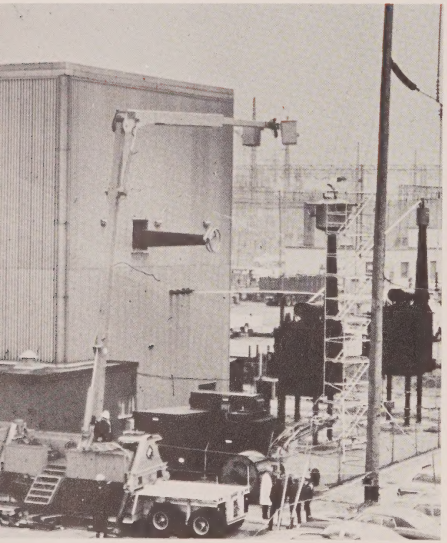


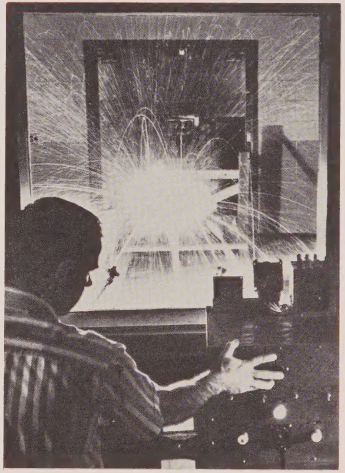


The procurement of insulated aerial units for barehand line-maintenance operations up to 500 kV has revealed a need for a critical study of insulation requirements and electrical design problems. Switching-surge and 60-Hz performance of design innovations developed in the laboratory are assessed using the Division's high-voltage facilities. Final certifications are carried out in accordance with ANSI standards.

The time-current fusing characteristics of transmission-line skywires are determined in the high-current laboratory to ensure the adequacy of skywires. Problems of a wide range are investigated relating to the design and application of power-system components such as switches, connectors, busbars and cable sheaths.

Accuracy of electrical measurements is assured by a standards-laboratory program that depends on national laboratories for the establishment of the electrical units. Portable reference standards for 60-Hz power and energy are calibrated to help maintain the accuracy of metering equipment.



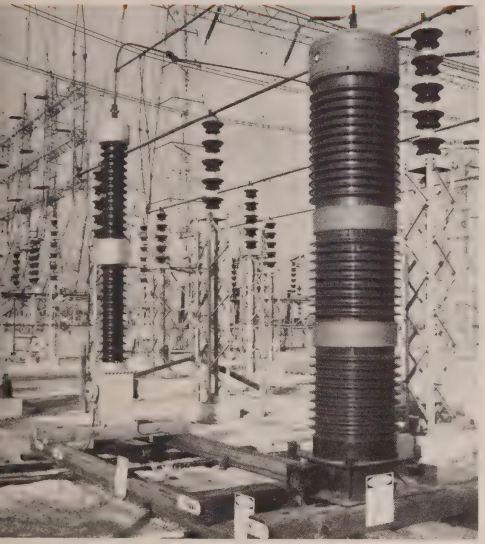


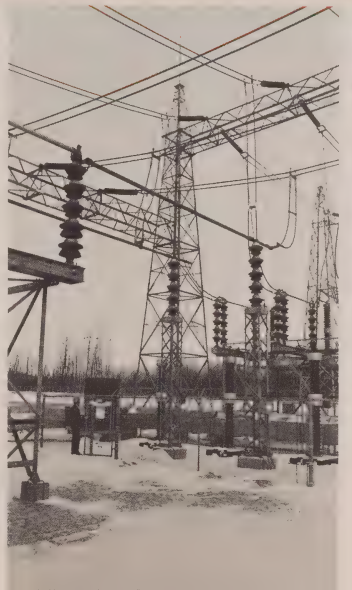
Stations

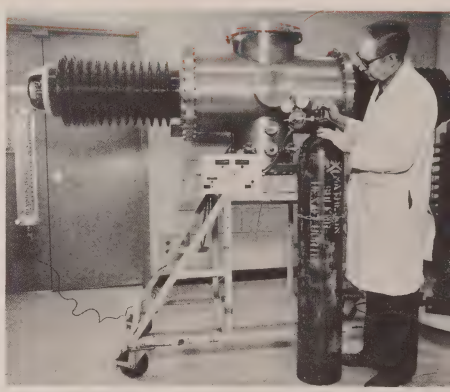
The causes of environmental and time-related changes in the accuracy of high-voltage capacitor voltage transformers are studied, in view of the increasing use of these transformers for revenue metering of interchange energy. The long-term accuracy of experimental installations is being continuously monitored as part of a program to find test methods that will identify in advance the better performing types.

When emergency loads and fault currents rise to higher levels, the resulting electromagnetic forces can subject station buses and structures to severe mechanical stresses. These conditions are studied both theoretically and with the help of large-scale models subjected to currents of up to 100,000 amperes.

Sulphur hexafluoride (SF_6), a gas with extremely good electrical insulating properties, has found wide application in compact substation design and, more recently, in ehv underground transmission. Both the reliability and the practical performance of this new insulation system are being evaluated in the laboratory. These studies are supplemented by a field-test program on a 500-kV SF_6-insulated transmission system, in co-operation with another Canadian utility and a manufacturer. This program includes dielectric-strength tests, load-cycling tests, analysis of fault-current-carrying capabilities and development of repair techniques.



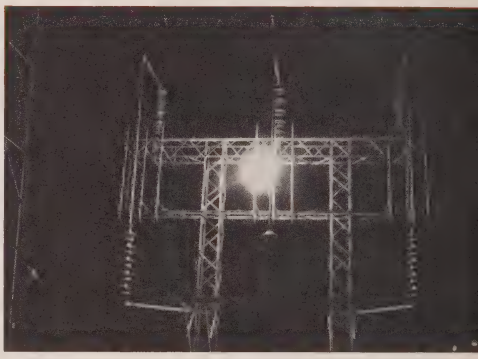




In a program to improve power-system performance, especially under transient fault conditions, novel high-voltage transducers for measurement of voltage and current are developed and tested. These supply low-level signals to solid-state devices that are being developed for power-system instrumentation and protective relaying. A special 30,000-ampere current shunt was designed and built to measure fault currents in experimental programs.

Voltage and current surges originating from disconnect-switch operations are a major cause of insulation breakdown in low-voltage wiring and of equipment damage in control and protective relaying systems in power stations. System tests have led to a better understanding of the mechanisms involved, and continual improvements of wiring layouts and shielding arrangements are resulting.

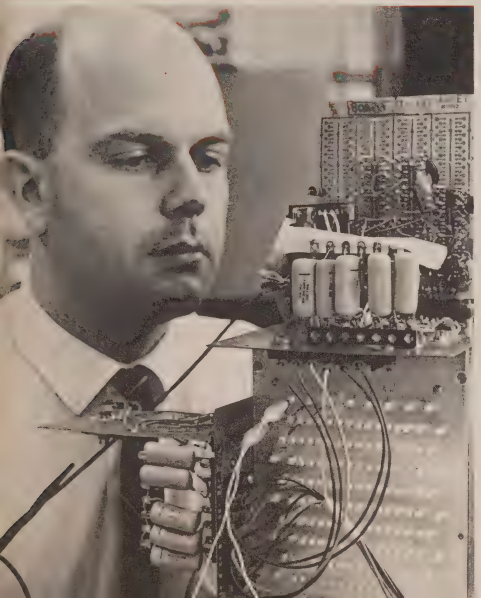
A parallel-pipe gap is shown flashing over during a system switching test. The pipe gap is more effective as a lightning-protective device than a simple rod gap. It is used at numerous 230-kV transformer stations where surge arresters cannot be used because of 60-Hz overvoltages.

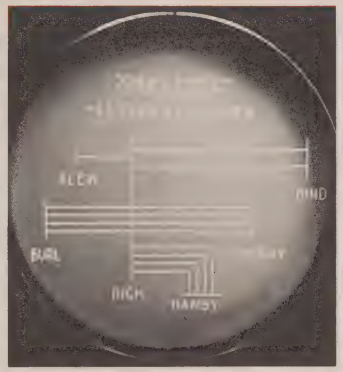


New instrumentation using solid-state integrated circuits and having a high order of reliability is being developed to meet the special needs of a large power system. One example is an optical coupler that provides an absolute electrical isolation while monitoring the operation of control relays.

The information yielded by modern electronic techniques is frequently beyond the capacity of normal meters and recorders. As a substitute for the latter, an experimental cathode ray tube display driven by a digital computer is under development. Great flexibility is possible since the display diagram is generated specially for each situation. Such improved man-machine interfaces permit better utilization of the station operator's skills.

Recent electronic developments have utilized increasing levels in complexity of circuitry. It is important that reliability is not lost as complexity is introduced. Printed circuit techniques based on optical reduction can cope with the complexity while retaining the basic advantages of simple devices.

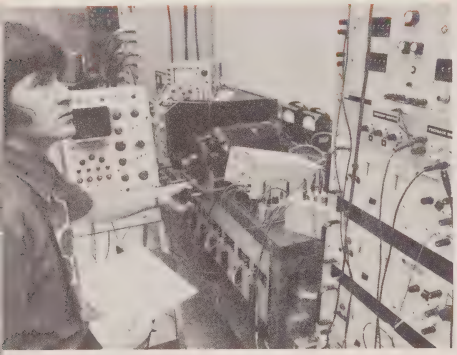


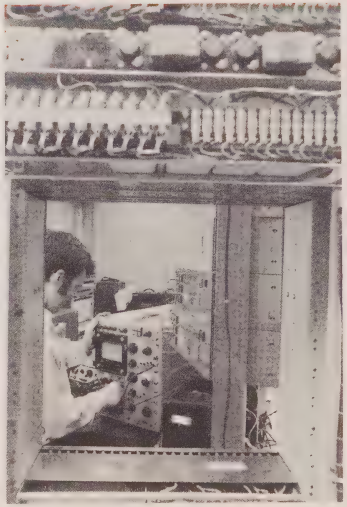


Solid-state protective relays are evaluated for application on the power system. New transmission-line protection is being developed that provides rapid line clearing in spite of fault-induced surges. Tests in the laboratory involve simulating system conditions as closely as possible. Fault-current offset and high-frequency transients due to switching operations are important effects which may be studied using a simulated transmission and synchronous switching control.

Power-system protection requires reliable transmission of information and circuit-breaker trip commands between stations in the presence of noise in the communication channel. Alternative methods of noise detection and use of digital codes are examples of schemes utilized in available equipment for this purpose. Tests are made on such equipment to evaluate its behaviour with the various types of power-system transmission links such as microwave, power line carrier and leased telephone circuits.

The co-existence of power lines with radio and telephone systems has led to many interference effects. For example, a power line in close proximity to the directional antenna array of a radio broadcasting station can distort the pattern of signal transmission from the array. Measurements and analysis are undertaken to ascertain factors in the design of power line structures that will minimize the influence of power lines on the radio-signal pattern.

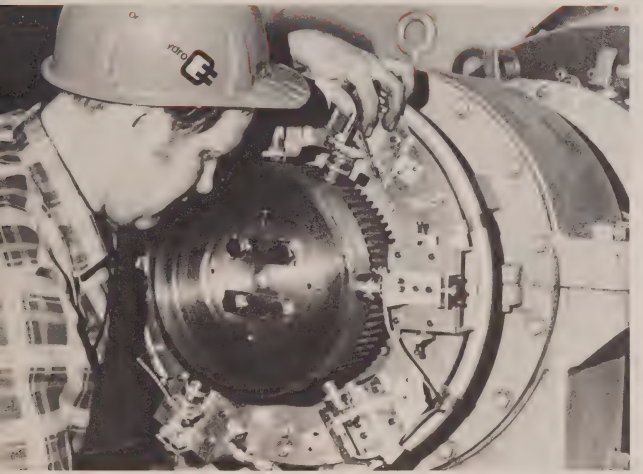


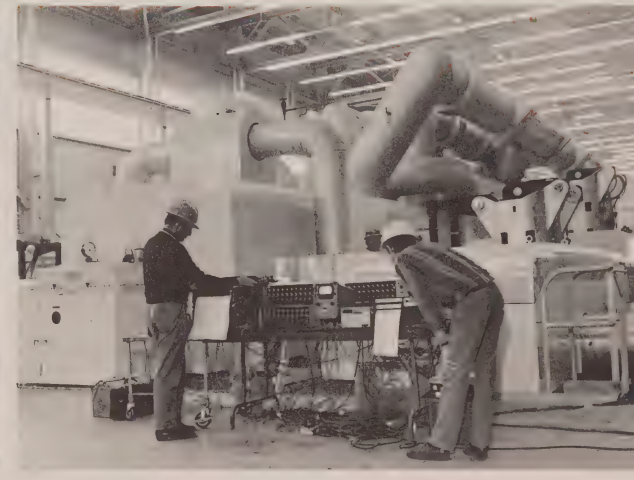


Generation

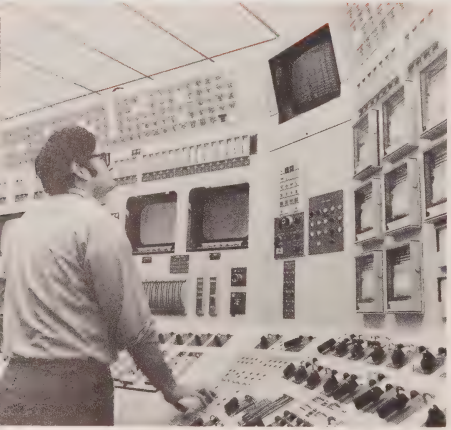
Extensive studies over the past 15 years of the behaviour of excitation systems in the field and their effect on transient and steady state stability have led to the introduction of static exciters. Equipment has been developed to derive a signal from generator shaft speed variations and to utilize this in the exciter control to damp out system oscillations. These arrangements have become standard on hydraulic machines. A similar arrangement on thermal machines was found to excite torsional mechanical oscillations, and extensive studies of mechanical and electrical properties of the machines were necessary to solve this problem. Alternative types of stabilizing signals are under development. The frequency response research techniques utilized in the foregoing studies are in use in developing further improved models of large machines. These models can be utilized in large scale transient stability programs to investigate system performance.

Tests are also made in the field to determine the efficiency and performance of large apparatus such as steam turbine generators and hydro generators. For load rejection tests performed on thermal machines during commissioning, extensive instrumentation is provided to monitor machine speed, valve movements, steam pressures and behaviour of governor and excitation systems.



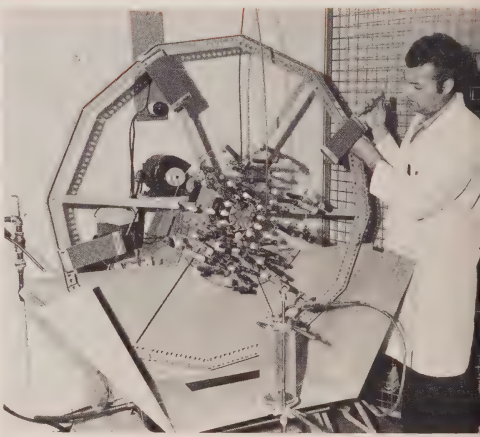


This control panel of a generating station includes a new sequence-of-events display to keep the operator informed of the status of electrical and mechanical devices in the station. The display with its storage capacity of 9,000 events, far exceeds the operator's reading capacity of a few events per second. As an alternative to a time-consuming search, a computer is arranged to interact with the operator using programs that locate the significant events and show these on the cathode-ray display screen.

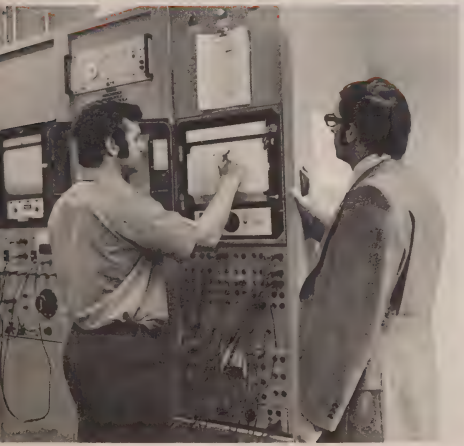


An electrical process for separating the heavy component of ordinary water is a possible source of heavy water for the HWR-PHW reactor. Successful operation will depend upon the generation of a very high electrical field in high-pressure dry steam. Experiments with a charged 50-micron wire in a steam-filled tube are showing whether the theoretical limit of the electric field can be approached.

Electrical insulating materials are tested both outdoors and indoors to determine their ability to withstand voltage on surfaces exposed to the weather. The tracking-endurance wheel, developed for accelerated indoor testing, rotates specimens through a water spray once every two minutes. The wetting, drying and flashover cycling produces in one day the same kinds and extent of deterioration as does nearly a year of outdoor testing.

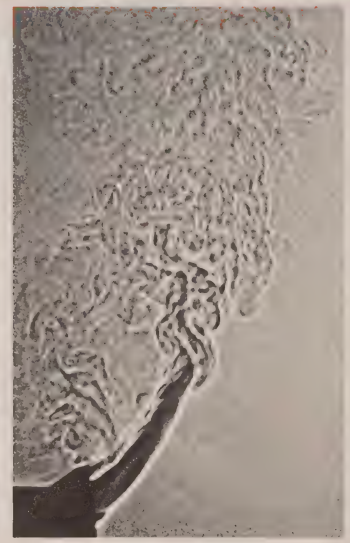


The performance of electric heating thermostats is being studied in a specially constructed test room. The test room represents a corner room of an electrically heated brick veneer bungalow. The roof and two sides of this room are exposed to air temperatures ranging from −30 to +90°F. The studies will lead to the development of a thermostat performance certification program.



While studying new heating systems, a simple, rugged and low-cost electric heating element has been developed to meet the need in systems-built apartments for a prefabricated ceiling-heating system which could be cast directly into the concrete floor slabs at the factory. The element consists of a double-insulated resistance wire fastened to a supporting metallic frame to form a heating mat.

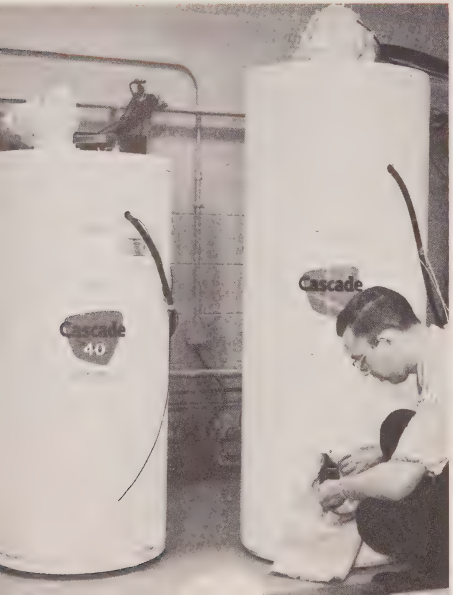
The air flow rising from an electric baseboard heater is made visible on a screen by a shadow-graph technique. This is used in developing designs that minimize wall streaking. Other electric-heating studies include field testing of residential heat pumps, and measurement of air infiltration into and humidity levels in residences.

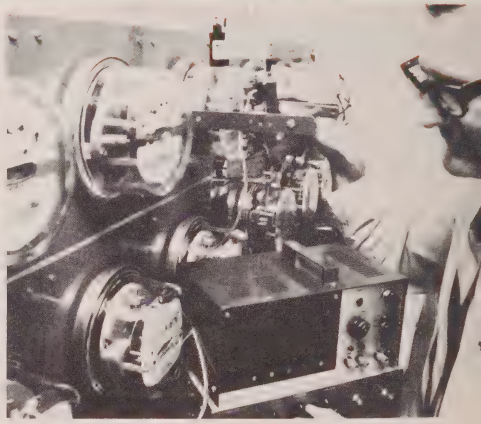


Electric water heaters of improved performance are being developed to meet increased customer demands for hot water as determined by a recent nation-wide customer hot-water-use survey. In addition to increasing the delivery performance, continuing studies are under way to increase the life of various components and thereby reduce maintenance costs.

In a new area of study, each part of the conventional residential wiring service, from pole to appliance, is being analyzed with a view to improving the convenience and safety of the service while reducing the cost of the installation. Initial emphasis is on a new technique for upgrading the service entrance capacity in older houses by eliminating the high-cost conventional stack.

With the aim of greater economy and reliability of electric-power metering, the performance of metering equipment is studied to find methods of prolonging accurate service life. In addition meter management systems are studied and developed to optimize the process of establishing and maintaining the accuracy of large numbers of watthour meters in service.

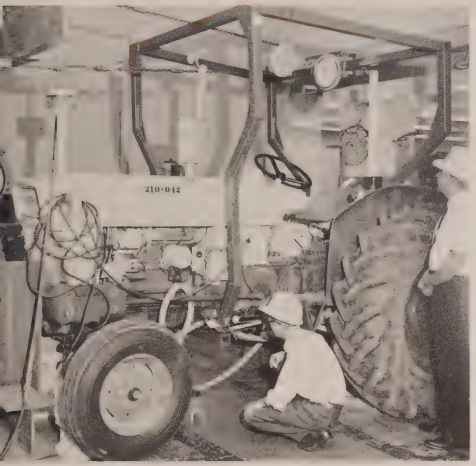


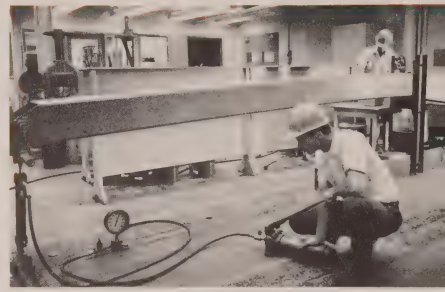


Mechanical Equipment and Materials

The Commission's widespread construction and maintenance operations require many and varied pieces of material and manhandling work equipment. The economic but safe use of this equipment in a demanding range of terrain, weather and emergency conditions, requires continuing study, test and change, of the test techniques as well as of the equipment itself.

One major area of study and improvement deals with the assessment of structural integrity and stability as illustrated, with a farm-type tractor roll bar being strength-tested (left), an off-highway vehicle carrying a radial-boom derrick and digger being stability-tested on a tilt bed (centre), and the endurance test of a glass-reinforced epoxy boom from a manhandling aerial device (right, upper). Also illustrated is a performance test of equipment used in tension stringing of conductors. Of parallel importance is the complementary work on cranes, aerial equipment and articulated vehicles dealing with operational methods, cold-weather considerations, determination of wear and fatigue patterns, establishment of basic safety criteria, and analytical methods of assessment.

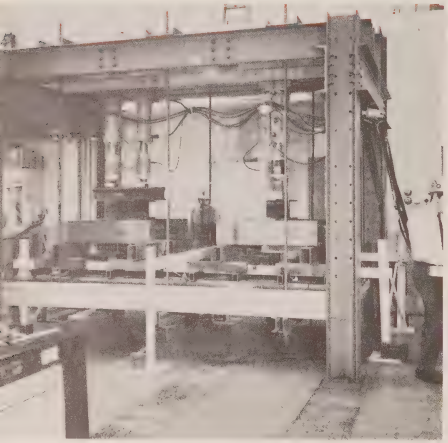


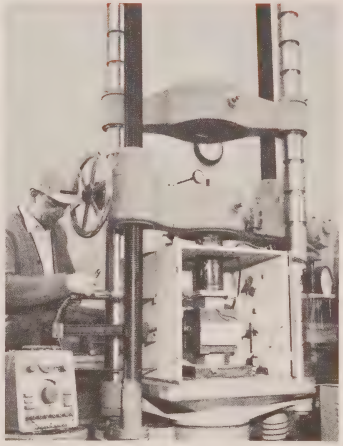


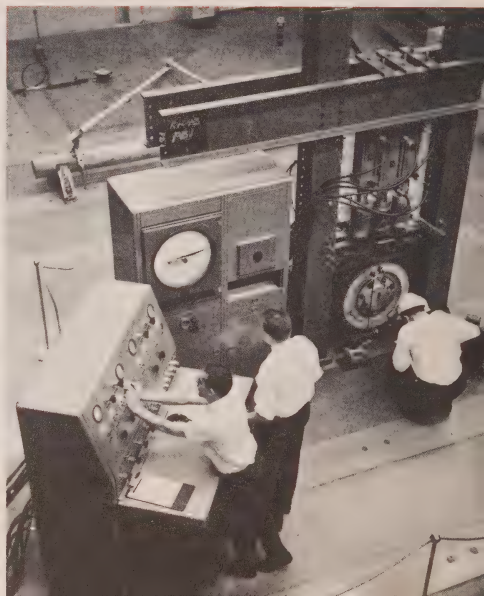
Safe and efficient use of structural materials, equipment and methods requires sound engineering judgment based on a knowledge of performance under the known and projected service demands. To satisfy, even anticipate, the requests for such information, as well as to carry out development work and problem solving, requires a wide range of structural and mechanical test facilities and skills.

The performance of a steel-reinforced elastomer is being tested at elevated temperatures, for use as a chimney "ligament". The application of load to a concrete-form panel and the quarter-million-pound proof-load on a gate wheel assembly are employing, in a variety of loading configurations, a versatile loading and reaction system involving a special floor and test frame.

Subject to the same technical inquisitiveness are the mechanical and structural properties and performance of line and station materials and equipment, both metallic and non-metallic, from towers to tools, from instrumentation to filter media, as well as those of materials, equipment and methods involved in the use of electrical energy.





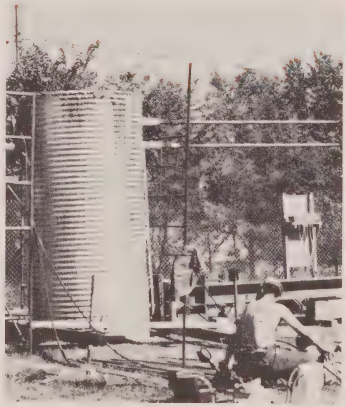


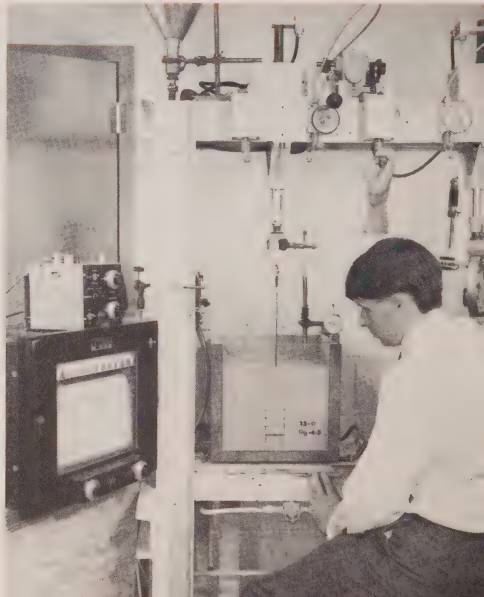
Ontario Hydro's operations must depend on the quality and performance of metals in an increasingly broad and vital role. In helping to ensure that metals will meet the requirements, the Research Division's metallurgists and other scientists use a scanning electron microscope to study the structures of materials. At magnifications of up to 100,000, it shows intimate details of fractured or corroded surfaces. The composition of pinpointed areas identified as being significant may be qualitatively measured by means of an X-ray spectrographic counter.

Another method of studying grain structure and defects is by means of an optical microscope. A metallographer is viewing a polished and etched specimen through the microscope to observe grain size and shape.

The steam and water pipes of large thermal generating stations involve many thousands of welded joints, each requiring careful post-weld heat treatment for removal of residual tensile stresses. Although induction coils of the type shown below are commonly used in stress-relief operations, studies have shown that other methods, such as resistance heating, may also be adequate, particularly on large-diameter pipes.

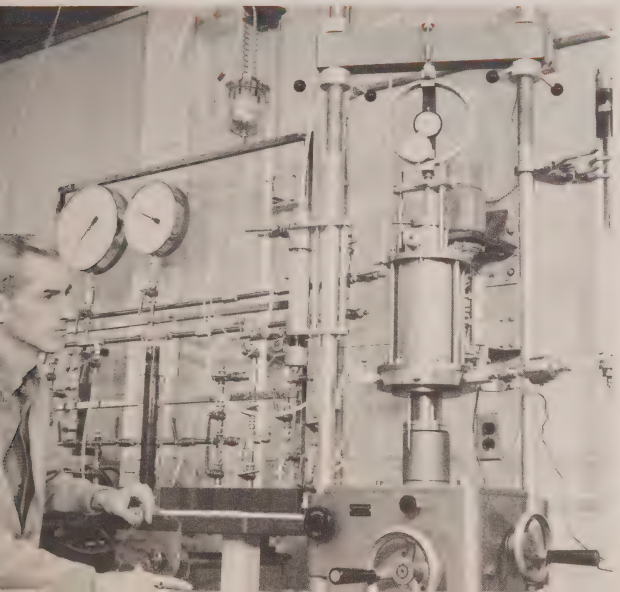
In soil investigations for power plants, transformer stations, transmission towers and the like, many problems arise for which there are no ready solutions. An example is the capacity of soil or rock to resist high uplift and lateral loads on transmission-tower foundations. In the design of steel-pole foundations, a special problem arises in determining the allowable lateral movement at ground level under the maximum loading conditions. To solve the problem, laboratory and full-scale field tests were performed. The results have been applied in the foundation design and the existing theories have been modified to agree more closely with actual behaviour. Many uncertainties still exist about the performance of foundations. Future studies will be concerned with the development of more rigorous solutions in regard to uplift and lateral stability particularly in regard to load-deformation behaviour. Instrumentation of full-scale structures will be continued as a means of achieving this result.





The triaxial-shear test shown is required in making foundation analyses. This high-pressure device was developed for better simulation of the natural stresses that act on soil. By means of an automatically operated servomechanism a sample of soil can be continuously consolidated under a zero-lateral-strain condition such that the stresses acting on the specimen closely represent those acting on an element of soil in place.

In the analysis of soil stability and foundation conditions, many simplifying assumptions must be made, and therefore the results are somewhat approximate. Hence, it is important that the behaviour of large soil- or pile-supported structures be monitored as a check on the design assumptions and the accuracy of the analysis. Shown are foundation instruments installed below the track of the bucket-wheel coal reclaimer at Lambton Generating Station. This unit operates automatically and is highly sensitive to differential settlements. At this site the soils are relatively compressible and extend down to as far as 140 feet to rock. The instruments determine the soil strains and pore-water pressures that occur at various depths below the track during operation of the unit.

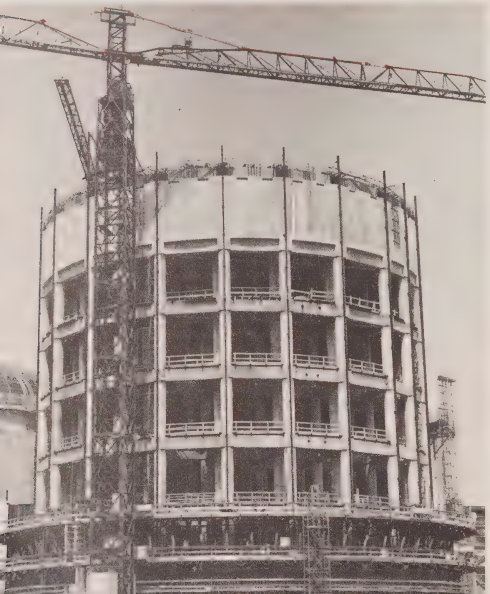


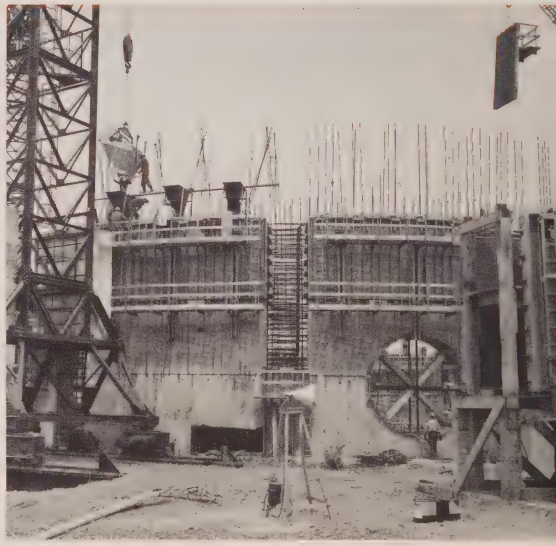
Concrete

The prime concern in the construction of a nuclear-station containment structure is its "air-tightness". The laboratory, therefore, checks the concrete for air permeability prior to construction, and, to minimize cracking of the structure, applies methods based on theory and practice in mix design, temperature control, placing sequence, and joint treatment. In vacuum buildings continuous construction by the slip-form method prevents the leakage of air by eliminating construction joints.

For shielding against radiation, concrete of high density can be used in place of normal concrete to save space if necessary, or for other reasons. The group of prisms, all of equal weight despite the marked differences in length, illustrate this effect. The two specimens at the left contain high-density aggregates for shielding, the centre prism is made of normal concrete, and the two on the right depict, respectively, lightweight concretes for structural and for insulation uses.

The construction of a nuclear-reactor enclosure building illustrates several pertinent features including the transfer of re-usable form panels and the delivery of concrete into the heavily reinforced wall via conical hopper and elephant-trunk drop chute. All operations are carried out under the watchful eye of a concrete inspector. To avoid shrinkage cracking, the primary wall sections are left to cool and shrink freely before concrete for the filler sections is placed.





The freezing and thawing test (centre) is performed with automatic equipment on prisms of concrete, and provides much comparative information on resistance to weathering. Outdoor tests (below) in an exposure plot near the laboratory supply information on durability, with maximum reliability.

Non-destructive test methods, sampling techniques and petrographic examinations are useful in determining the condition and rate of deterioration of concrete structures. The amount of concrete repair needed is inevitably bound to become greater, or course, as concrete structures increase in number, and as they become older.

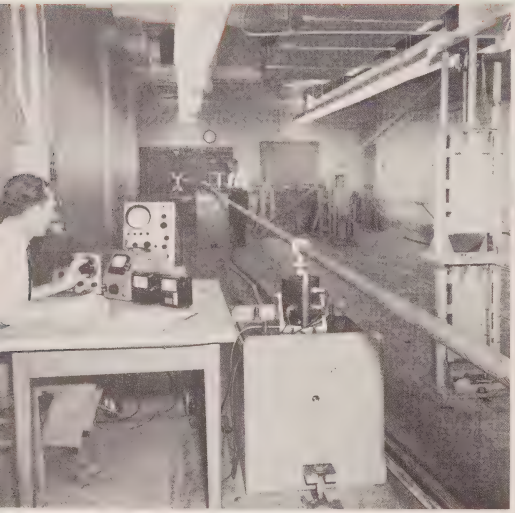
In repair and in somewhat special construction work, epoxy resins and other materials developed in recent years, are finding increasing application. Illustrated is the cold-weather trial of epoxy resin "concrete" cast as a levelling course for rock, to support the base plates of transmission towers. With heat for curing, this material permits tower erection to proceed within a few hours whereas conventional concrete, although less expensive, requires a construction delay of at least several days.

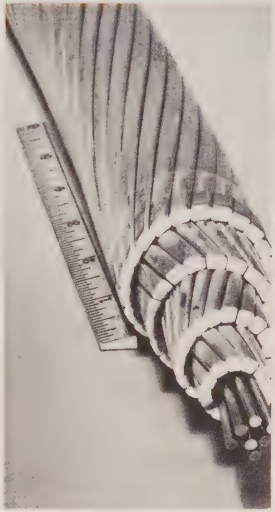
Vibration, Noise and Stress Analysis

Wind-induced "aeolian" and "galloping" vibration in overhead power conductors can result in damage to the conductors and line hardware, and in power outages due to contacts between galloping conductors. Computer-aided mathematical analyses, and tests on indoor spans and full-scale outdoor spans, provide data which lead to improved designs and applications of vibration control devices.

One such improvement (shown below) is a conductor, developed jointly with a manufacturer, which exhibits sufficient internal damping to control aeolian vibration even at tensions considerably above that permissible for conventional conductors fitted with dampers.

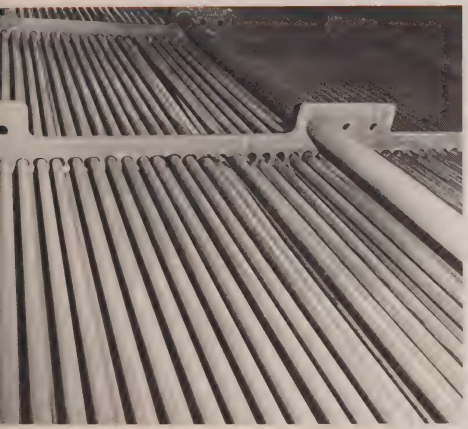
The aerodynamics of conductor galloping, still rather imperfectly understood, is being investigated in a series of wind-tunnel tests. Better knowledge of this aspect of the basic dynamics is expected to assist in achieving a solution to the galloping problem. Various damping proposals studied on service and full-scale test lines could provide adequate control of galloping which would lead to more compact and economic transmission lines.

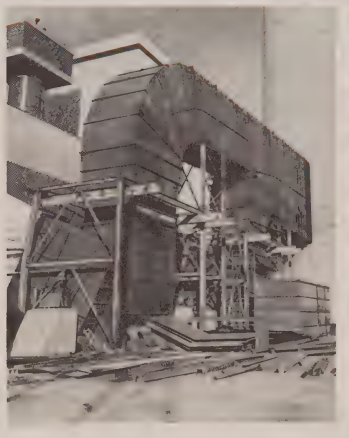


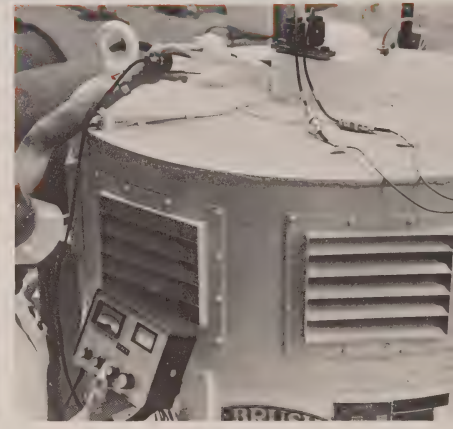


Vibration of equipment and structures is studied to arrive at means for prevention of failures and solution of operating problems. For example, the heat-exchanger tubes in the photo show excessive wear damage. Fluids or gases flowing over the tubes can excite vibrations which result in impact causing wear and fatigue at the interface between the support plate and tubes.

Vibration also occurs rather generally and sometimes causes trouble in other equipment such as rotating machinery and pipes and ducts. Panels of the duct work of large exhaust fans can vibrate to a degree sufficient to cause fatigue failure of structural elements. Studies of balancing of rotating equipment to avoid destructive vibration, and of the monitoring of unbalance, are directed at improving equipment serviceability. This is particularly pertinent in nuclear plants where some equipment operates in areas inaccessible for normal inspection.



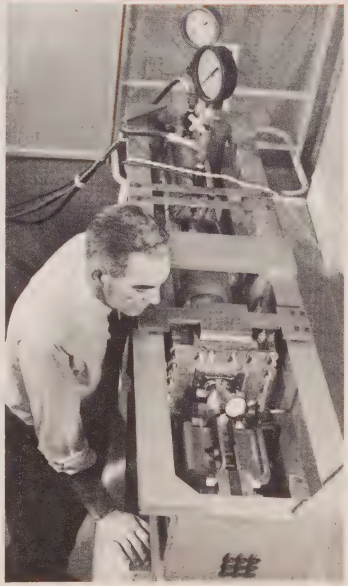




Studies are made to reduce noise from transformers, fans, steam blow-off valves, office machines and other such equipment. An anechoic room, with its echo-free walls, is shown being used for acoustic studies of screens used in "landscaped" offices. In landscaped or traditional offices, solutions to acoustic problems include use of barriers for privacy maintenance, absorption of sound, and masking of objectionable frequencies with a suitable non-irritating background noise.

Theoretical and experimental methods are used to determine the load stresses in structures. In the specially designed fatigue machine below, an investigation was carried out to determine the stress concentrating effect of various tube-to-tubesheet attachment arrangements for the heat-exchangers of nuclear power plants. Such fatigue studies can help achieve economic designs.

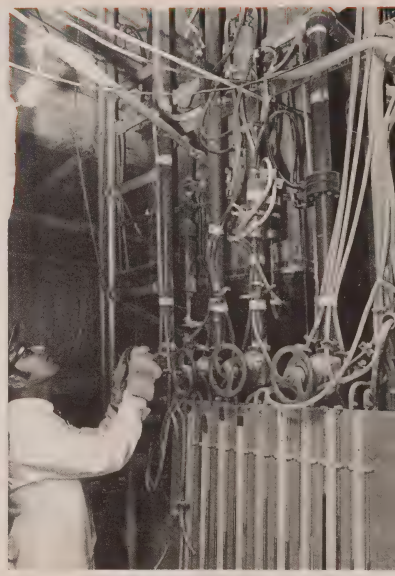
During construction, strain gauges, pressure cells and displacement meters are installed in structures to study in-situ field loads. Illustrated below is instrumentation being installed in a thermal-plant chimney. The pressure cells measure wind pressures on the chimney at several elevations while the strain gauges attached to the reinforcing steel measure stresses. These field load data are applied to improve structural designs.



Chemical and Related Studies

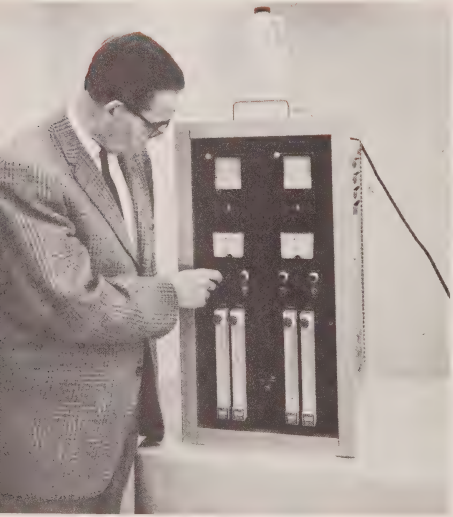
Atmospheric Physics – The design of chimneys to control the ground-level concentration of pollutants depends on the ability to predict how pollutants released from the chimneys will be dispersed in the atmosphere. Dispersion in turn is governed by atmospheric phenomena. Extensive studies are carried out at existing and future generating station sites to determine how plumes are or will be dispersed under varying atmospheric conditions. Statistical data is obtained on certain atmospheric phenomena, such as the frequency and height of temperature inversions, so that station chimneys can be adequately designed for air pollution control.

Sulphur Dioxide Removal – Processes are developed for containing pollutants at the source and thereby reducing emissions to the atmosphere. A limestone scrubbing process in a spray tower for removing sulphur dioxide from the flue gases has been developed and has been operated for more than two years in a pilot plant at Lakeview Generating Station. Preliminary engineering design for a prototype has been completed. Other pollution control processes are being studied.



Pollution Monitoring – Concentrations of pollutants in the atmosphere near fossil-fueled generating stations are measured to assess the effects of the stations on ambient air quality. Pre-design surveys are conducted eight to ten years before the station operates, and surveys are resumed three years before operation and continued indefinitely. Sulphur dioxide, oxidant and particulate concentrations are measured together with wind direction and velocity. These data together with station operating data, such as amounts of fuel burned and sulphur content of fuel, are used to assess the effects of each station on ambient air quality.

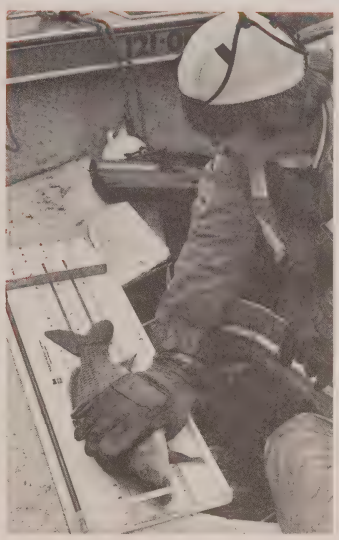
Pollutants Analysis – Determining the chemical composition of the flue gases is a painstaking task involving quantitative analyses in the parts per million and parts per billion ranges. To ensure accurate results, a balance must be obtained between the amount of a substance in the fuel and the amounts found in the flue gas and ash. After satisfactory quantitative data are obtained, the resulting ground-level concentrations are estimated and the possible effects assessed.

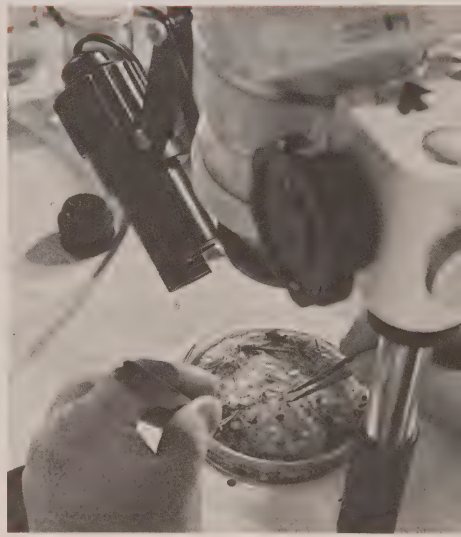


Aquatic Biology — Surveys are conducted at most of the large nuclear and fossil-fueled generating stations in southern Ontario to provide factual information about the effects on aquatic life of the warm water discharged from power-station cooling systems. In addition, surveys are carried out at future generating station sites so that possible environmental effects can be predicted and taken into consideration in the design of the station. The studies also give background data for comparison with data taken after the generating station is in operation.

During spring, summer and fall, monthly samples are taken of phytoplankton, periphyton, zooplankton, benthic macro-invertebrates and fish. Examination of these samples gives an assessment of the species, composition and productivity of the various trophic levels of the aquatic ecosystem.

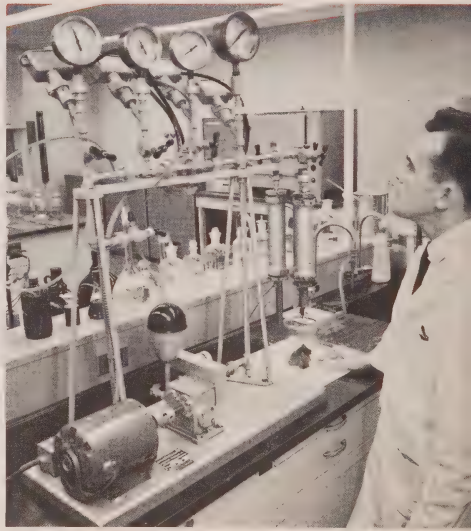
Studies are under way to determine the quantities and types of materials used in the generating stations which may eventually find their way into surface waters. Possible effects of these materials are considered to establish the need for research and development work in future water quality-control systems.



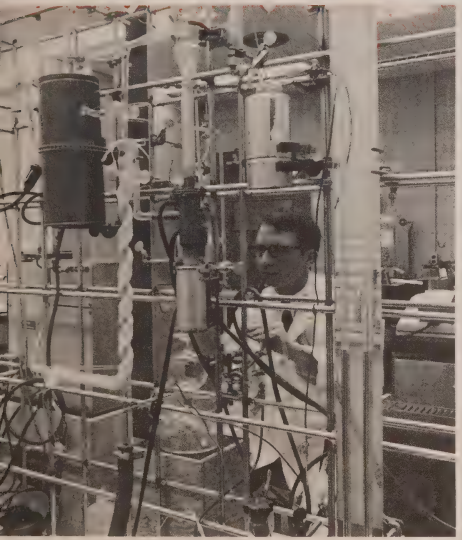


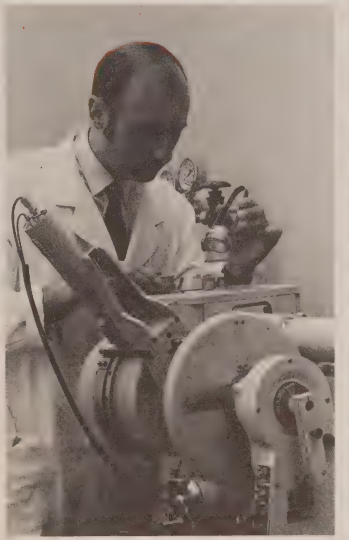
Materials Protection — Research is done on maintenance systems for towers and other structures located in severe environments, protective coatings for underground and underwater equipment, chemical-resistant liners for water-treatment plants and flue-gas scrubbers, high-temperature-resistant coatings and wood preservation. Studies are made of the properties and performances of joint sealants, roofing systems and other organic building materials. Surface preparation and application techniques are investigated to achieve better coatings performance to reduce cost and to improve specifications. A range of equipment such as weatherometers, salt-spray and humidity cabinets and other special test apparatus is available for use in these studies. Information on the field performance of the various products is obtained from test sites maintained in industrial and semi-urban atmospheres.

Petroleum Products — Studies are performed on low-temperature lubricants for work and transport equipment, the effects of radiation on lubricants, the degassing and filtering of electrical insulating oils and the leaching of inhibitors from steam-turbine oils. The viscometer (below) determines the flow properties of a grease. The values of this property are important for greases used in the automatic lubricating systems of hydraulic turbines.



Instrumental Analysis – Gas chromatography and infra-red spectrophotometry aid in studies of the effects of electrical stress in insulating liquids, and the photochemical degradation of plastics and protective coatings. Nuclear fuels, wood preservatives, building-maintenance products and herbicides are also analyzed for acceptability. X-ray fluorescence spectrography is used for the analysis of the elemental composition of materials that could occur in different aggregates of gas, liquid or solids such as alloys with corrosion products or solids in liquid dispersions. Other analytic methods that can be used are arc-spark emission spectrography and flame-mode atomic absorption. Analysis of low- and high-alloy steels, brasses, and bearing metals helps to solve metal failure, wear, welding, corrosion resistance, and other metallurgical problems. The trace-element composition of fuel, fly ash and flue gas are determined to aid in the assessment of possible pollutants from fossil-fueled generating stations. Flameless atomic absorption and ultraviolet-visible spectrophotometers are used for this purpose. Gamma-ray spectrometry is used for the study of radioactive corrosion products within the heat-transport systems of nuclear generating stations, and of the trace element composition of a large variety of radioactive samples.

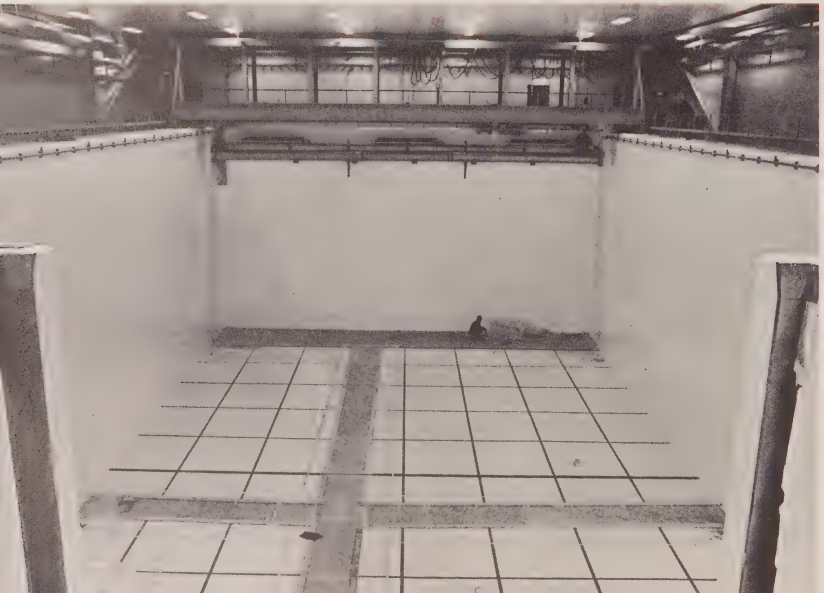


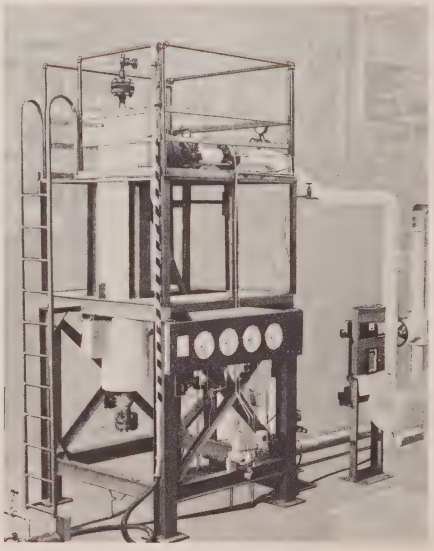


Nuclear Technology – Radiation-resistant coating systems have been developed to provide durability and easy decontamination of vault and containment surfaces. More severe environments, such as in the spent fuel bay with its high radiation exposure and demineralized water, require special systems for grouts and liners.

Plastics and elastomers are evaluated for resistance to radiation exposure, high temperature and ozone for such applications as diaphragms, seals and electrical insulation.

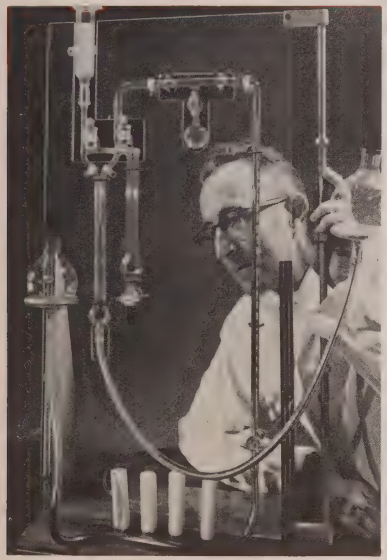
Deposits in the heat-transport system are characterized and identified. Corrosion effects on equipment from decontamination procedures and materials are measured. The removal of radioactive particulates from heat-transport systems by deep-bed granular graphite filters is being studied. Other investigations are concerned with the removal of heavy water from reactor cores for decontamination and minimization of heavy-water downgrading during the removal process.

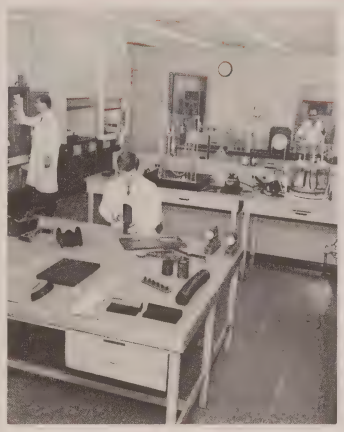


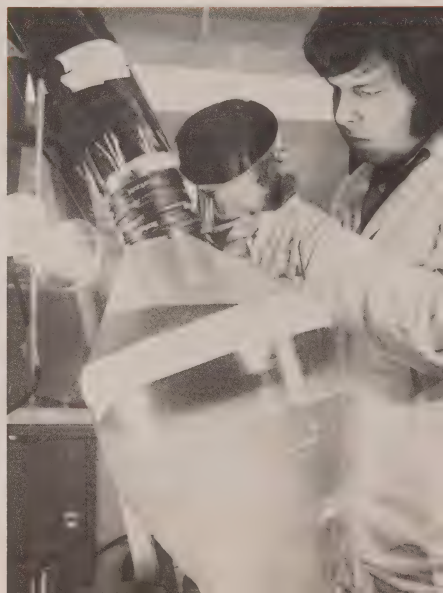


Thermal Insulation – Ontario Hydro's insulation applications range from the insulation of electrically heated houses to that of giant boilers and turbines in generating stations. Various types of apparatus are used in the testing of insulating materials such as the equipment shown for the determination of closed-cell percentage in rigid cellular plastics. Other research programs relate to the design, development and specification of insulating materials. Calcium silicate, polyurethane foam and stainless steel reflective thermal insulations are tested for performance in the temperature range of −55°F to 1030°F.

Plastics and Elastomers – Design criteria are developed for exhaust duct joints, chimney expansion joints and bearing pads exposed to elevated temperatures in fossil-fueled generating stations. Fire testing of grouped plastic insulated cables in vertical runs is undertaken to provide basic data for the modification of cable runs in existing stations, to determine the effectiveness of fire-stop barrier systems, and to develop superior fire-resistant cable compositions. Elastomers have been investigated for concrete-wall bearing pads, equipment seals, roof expansion joints, and door seals for nuclear stations, and for use as vibration suppressors on overhead lines. Moulded epoxy and urethane joints and terminations for high-voltage underground cable service up to 138 kV are in the development stage. These prototypes are being investigated for compact-station bus-bar service.





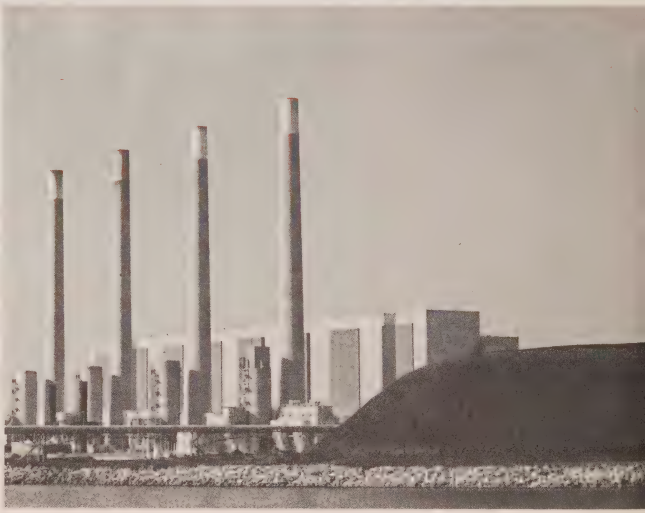


Operations Research

The increasingly complex problems that face today's management arise from the advent of more extensive and varied production facilities, a greater range of human skills, massive and speedier information flow, expanding technology, and interactions with the social, industrial and financial environment. Hence, management decisions now require a more comprehensive assessment since they represent a far greater commitment than in the past.

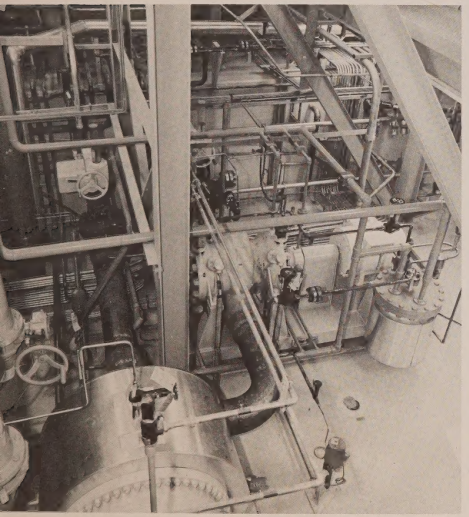
As a result, in recent years, organizations have introduced operations research units with appropriate scope, skills, and techniques. These units assist in reducing guesswork and uncertainty, and evolve and provide quantitative comparisons of alternatives. Three applications are illustrated here. Others include vehicle-replacement policy, long-range load forecasting, management information systems, simulation of operations, economic concepts in pollution control and R & D program appraisal.

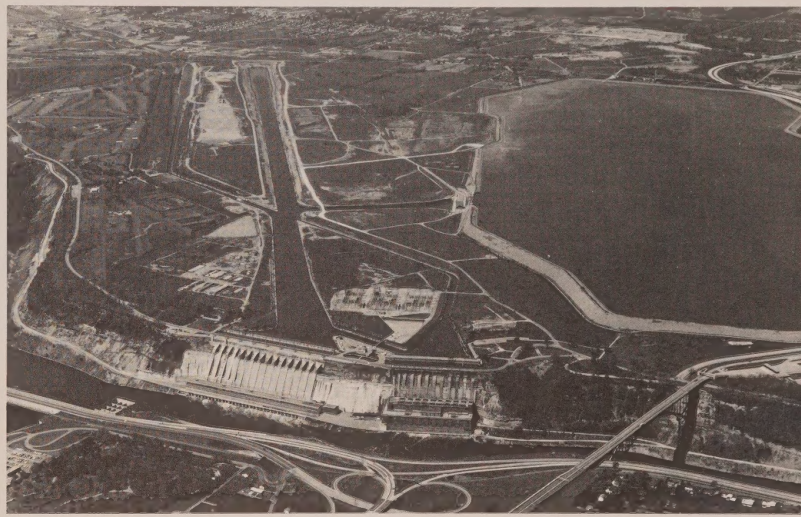
For Ontario Hydro's fossil-fueled generating stations, the determination of fuel requirements and reserves is important. Variations in power demands and in hydro-electric and other resources make an exact estimate unattainable. A probabilistic model of the problem takes into account the above factors as well as the cost of additional fuel and purchased electrical energy. The model then provides relationships between fuel reserves, security levels and over-all costs and identifies optimal operating policies.



Studies have been carried out in a variety of areas related to the supply, warehousing and distribution of material for the construction and operations of the power system. Advanced techniques of inventory control have been developed and management information systems introduced. Comprehensive evaluations of alternative physical stores systems have been made, with management acceptance of proposals for a highly integrated, rapid delivery concept. Management's development of necessary warehousing facilities and other resources for an effective supply system has been achieved through long-range forecasts of future material requirements.

The Beck-Niagara power stations and the associated pumped-storage facility need to be operated in a way that, together with other stations, will meet the demand and also maximize the economic worth of their output. Factors such as varying efficiency with changes in output, water levels, and number of units on line, complicate this problem. A scheduling model based on the use of the operations research technique of dynamic programming achieved major strides in its analysis.





Main Areas of Investigation

On the preceding pages the brief descriptions and accompanying illustrations have provided some insight into the breadth of the Division's research and development program. Within the limits of this booklet, however, only a cursory account could be given of the wide range of problems relating to the design, construction, operation and maintenance of the power system, to the efficient use of electrical energy, and to safety aspects. Reports in greater detail on many of the subjects dealt with are available as published technical papers or in the pages of Ontario Hydro Research Quarterly.

Analysis of Structures, Machines and Components

Air Pollution

Applied Mechanics

Building Components, Materials and Techniques

Communications and Telemetering

Concrete and Masonry

Corrosion

Electrical Insulation

Electric Metering

Electric Power Apparatus

Electric Power Utilization

Electronics Applications

Engineering Properties of Soil

Fuels and Lubricants

Geological Techniques

Grounding

Lightning and Switching Surge Protection

Line Structures, Materials and Hardware

Materials Protection

Metals and Alloys

Noise Problems

Nuclear Technology and Related Studies

Operations Research Applications

Plastics and Elastomers

Power Transmission and Distribution

Preservation of Wood and Other Organic Materials

Safety Measures

System Control, Protection and Switching

Thermal Insulation

Tools

Vegetation Management

Vehicles

Vibration of Machines, Conductors and Components

Water and Water Treatment

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